IMAGE PROCESSING TECHNIQUES FOR ASSESSMENT OF DENTAL TRAYS

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Abstract-**A tray selected for the dental patient must adapt to the curvature of the teeth and allow the impression material to be in appropriate thickness everywhere. Generally, the impression trays are selected by the practitioner via testing them in the mouth. The present study was conducted to develop an automated technique for the selection of an appropriate tray for the patient. This technique was used for the alignment of six brands of perforated metal trays with 170 lower arch cast models collected from patients having Angle Class 1 type occlusion with minor malocclusions. The cast models and trays were scanned into a computer and critical points of casts and skeleton of the tray bases were collected. After alignment of casts and trays using a distance based alignment routine, the trays which most adopted the curvature of the casts were evaluated using the residual distance of alignment. The alignment was repeated for selected subsets of the points and minimum point set that is necessary for identification of the correct tray was identified. This method can be used in a routine setting eliminating trial and error or to design better trays to fit the needs of a given population.**
Keywords - **Dentistry, tray, cast, distance based alignment**

I. INTRODUCTION

A dental cast is widely used in dentistry for working on dental prostheses. Due to the problems involved in working within the mouth, the tooth shape and position, which provide fundamental diagnostic information in dentistry, are generally measured in dental casts [1]. An accurate working cast is essential for making a crown or a fixed partial denture fit the abutment precisely [2].

Accuracy of the impression is the most important factor for a successful prosthetic appliance. The thickness of the space between the tray and the preparation is one of the important factors related with the dimensional stability of the impression material. In the literature, the sufficient space for the impression material between the tray and the mucosa and teeth is recommended not to be less than two millimeters.

The variable thickness of the impression material in each stock tray may result in dimensional changes and inaccuracies in the cast [3-8]. It is known that custom trays affect the prognosis of the prosthesis, however it is also known that standard trays are widely used [9]. The time and cost required to construct custom-made impression trays have channelled the manufacturers to provide quick and less-expensive alternatives. Stock trays are useful for some procedures but their flexibility and construction vary [8]. Even tough the custom perforated trays demonstrate satisfactory results, a wide range of measurements indicate that the use of this type of tray does not guarantee predictable results [10].

The ultimate effect of an expansion on the accuracy of the impression depends upon the general contour of the impression tray and the adhesion of material to the tray [11]. There are no scientific data and records about the principles used to produce the dentulous stock trays. Generally, dentists choose the impression trays by testing the trays in the mouth. However, this may cause inaccuracies in the cast and affect the accuracy of the prostheses [12].

Image alignment or registration is a common task in image processing. It is encountered in many fields such as remote sensing, where two-dimensional data sets must be registered, and in biomedical imaging, where two- or three-dimensional image contours and surfaces are collected routinely. We employed distance based alignment technique to register selected two-dimensional points on the casts to main axis of the trays to measure how good their fit were [13].

The purpose of this study was to develop a method to help the practitioners to find the tray which best adopts the curvature of the patient automatically. The method developed here can also be used to design better tray shapes if it is applied to a greater number of casts representative of the general population.

II. METHODOLOGY

170 fully dentate lower arch models were collected from 170 patients having Angle Class I molar relationships with minor malocclusions and teeth including second molars fully erupted without loss of tooth material mesiodistally.

Six brands of metal standard trays with perforations were collected, each with a different size and shape. The 24 different trays for the lower arch in total, are given in detail below:

1- Teknik (Turkey, size 1, 2, 3)
2- Medesy (Italy, size 1, 2, 3)
3- Inox (Italy, size 1, 2, 3, 4, 5)
4- Zhermack (Italy, size 0, 1, 2, 3 ,4)
5- Hammacher (Germany, size 1, 2, 3)
6- Ultradent (U.S. size 1, 2, 3)

The digital images of the casts and trays were obtained with a regular desktop scanner at 100 dpi resolution. The images acquired by the scanner were calibrated via scanning test objects with known dimensions. Pixel aspect ratio error of the scanner was compensated.

Initial image analysis tools were written in NIH Image programming language. The macro written for the casts was used to interactively mark the previously decided 13 points on the images, giving the two-dimensional coordinates. As it is shown in Figure 1, these selected landmark points were:

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- The middistal points of left and right second molars (#1, #13).
- The midpoints of left and right molars (#2, #3, #11, #12) and premolars (#4, #5, #9, #10) occlusal faces in vestibulolingual and mesiodistal direction.
- Canine cusp tips (#6, #8).
- Midmesial point of central incisors (#7).

In tray images, tray base was first segmented by semiautomatic thresholding and the center line of the base was found automatically using binary image analysis methods (skeletonizing) (Fig. 2.). The trays were taken as reference objects and casts were taken as test objects and a two-dimensional rigid body transformation was used to align the tests with the references. This image alignment methodology operated with pixel-based (or voxel-based for three-dimensional) descriptions of the objects. The objects were represented by point sets in an Euclidean space and the Euclidean distance transform was used to evaluate the residual distance of the test object as it was iteratively aligned to the reference object, and the Marquardt-Levenberg optimization algorithm was used for optimization. For two dimensions, the distance map was in the form of a two-dimensional array, whose entries were two-dimensional vectors from the closest point in the object to a given pixel[13].

Series of alignments were made between teeth and trays using MATLAB. The 13 landmark points belonging to the casts mentioned above were aligned with skeletons of all of the tray bases. The mean, standard, median and maximum residual errors between each cast and tray data were obtained after each optimization. For each cast, a matching tray was found among different sizes of a brand and a second time among all trays. The mean of the mean residual errors of all matches was used to evaluate the best set of trays (Fig. 3.).

One tray from each brand was taken as the master tray, the other trays of the same brand were aligned, and the areas where tray base skeletons showed significant difference were observed. This was used in selecting the subset candidates of the reference points. Four subsets of points were selected, these were as follows:

1. The middistal points of right and left second molars and the midpoints of left and right second premolars occlusal faces in anteroposterior and mesiodistal direction (#1, #4, #10, and #13 in Fig.1.)
2. The middistal points of right and left second molars and the midpoints of left and right first premolars occlusal faces in anteroposterior and mesiodistal direction (#1, #5, # 9, and #13 in Fig.1.)
3. The middistal points of right and left second molars and left and right canine cusp tips (#1, #6, #8, and #13 in Fig.1.)
4. The middistal points of right and left second molars and the midmesial point of the central incisors (# 1, #7, and #13 in Fig.1.)

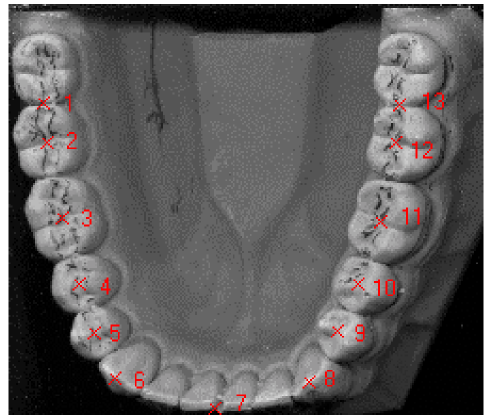

Fig. 1. All 13 points marked on a cast (see text for the detailed info)

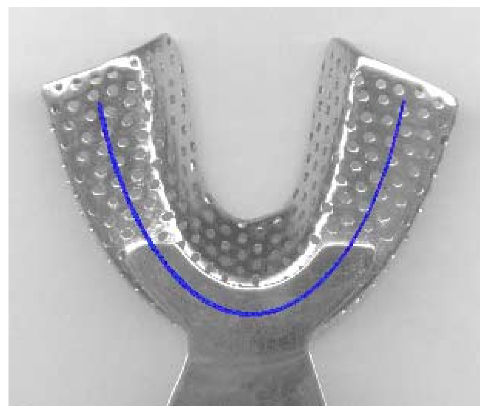

Fig. 2. Image of a tray and its skeleton

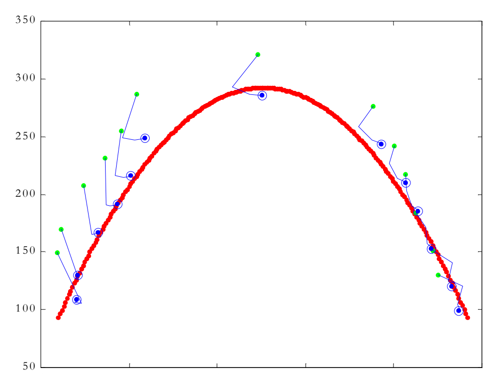

Fig. 3. Figure of a tray (red line) and a cast (blue) during optimization. Each blue line displays the trajectory of a test point during the alignment.

The complete alignment as it was done for 13 points was repeated for these four groups of points. The tray matches of these subset alignments were compared to the original matches using all 13 points.

III. Results and discussion

If the alignment was done seperately for each brand of trays, the mean of residual errors were as follows:

- Teknik: 10.1066 pixel
- Medesy: 6.2295 pixel
- Inox: 5.5922 pixel
- Zhermack: 5.2911 pixel
- Hammacher: 4.8346 pixel
- Ultradent: 4.4816 pixel

Here the errors were mean errors over all of the matches of different sizes of trays of a given brand (1 pixel= 0.25 mm). The two brands that gave the least error were Ultradent and Hammacher.

Initially 13 points were used for the analysis and for each cast the matching size of a given brand was identified. Alignment of the subset groups were compared to this and results are shown in Table 1. Generally, subset alignment gave the correct matches with the original full point alignment. The two exceptions were: 1) the first group of points failed to find the correct tray sizes in two out of six brands, 2) The second tray could not be identified correctly in any of the subset alignments. The subgroups two to four gave successful results, but the fourth set was preferred because it used only three points.

Current results are restricted to two-dimensional data. Similar techniques can be used in three-dimension, if trays and casts are converted into three-dimensional models. Distance based alignments can also be performed in three dimension. Three-dimensional methods can be more appropriate in designing the trays but for routine clinical use, a simpler method -such as the one presented here- would be more practical.

IV. Conclusion

Different levels of fit between the collected group of dental casts and various tray sets are shown. Some sets were found to have a better design for our population. According to the results of subset alignment, three points were found to be adequate in selecting the appropriate tray. This method can be converted to a small program or a chart to help dentists in tray selection using a minimum set of measurements and eliminating trials.

V. Future work

The current results belong only to the lower arch cast models. The method is being implemented for the maxillary arch models.

TABLE I

The results of the four subset alignment compared with the results belonging to full set alignment. 100% means all of the alignments in the subset group found the correct size.

	1st brand	2nd brand	3rd brand	4th brand	5th brand	6th brand
1. group of marks	1%	56%	100%	100%	100%	100%
2. group of marks	100%	63%	100%	100%	100%	100%
3. group of marks	100%	60%	100%	100%	100%	100%
4. group of marks	100%	58%	100%	100%	100%	100%

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